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Valuing Water for Chinese Industries

A Marginal Productivity Assessment

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The marginal productivity of water used for industry varies among sectors in China, but there is great potential for the Chinese government to save water by raising water prices to industry, to encourage water conservation.

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Summary findings

Using plant-level data on more than 1,000 Chinese industrial plants, Wang and Lall estimate a production function treating capital, labor, water, and raw material as inputs to industrial production. They then estimate the marginal productivity of water based on the estimated production function.

Using the marginal productivity approach to valuing water for industrial use, they also derive a model and estimates for the price elasticity of water use by Chinese industries. Previous studies used water demand functions and total cost functions to estimate firms' willingness to pay for water use.

They find that the marginal productivity of water varies among sectors in China, with an industry average of 2.5 yuan per cubic meter of water.

The average price elasticity of industrial water demand is about –1.0, suggesting a great potential for the Chinese government to use pricing policies to encourage water conservation in the industrial sector. Increasing water prices would reduce water use substantially.

This paper — a product of Infrastructure and Environment, Development Research Group — is part of a larger effort in the group to understand the economics of industrial pollution control in developing countries. Copies of the paper are available free from the World Bank, 1818 H Street, NW, Washington, DC 20433. Please contact Roula Yazigi, room MC2-533, telephone 202-473-7176, fax 202-522-3230, email address ryazigi@worldbank.org. Policy Research Working Papers are also posted on the Web at www.worldbank.org/research/workingpapers. The authors may be contacted at hwang1@worldbank.org or slall1@worldbank.org. November 1999. (23 pages)

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Valuing Water for Chinese Industries:

A Marginal Productivity Approach

I. Introduction

Water use can be broadly divided into three categories. These are agricultural, industrial, and domestic uses. There have been numerous studies examining the demand and value of water for domestic or residential use.[i] However, the extension of this research to industrial sector and agricultural sector has been very limited. The dichotomy in water valuation research between domestic and industrial (and agricultural) use is heightened in developing countries, partly due to the lack of reliable information on water consumption and pricing at the firm level.

The role of water on industrial production stems from its role as an intermediate public good with an active part in production processes that reduces the unit cost of production. Water use studies for industry were performed by estimating water demand models where the ratios of total expenditures to total quantity purchased were used as proxies for prices. Estimation of cost functions was also conducted where water was included as an input along with labor, capital, and materials, and the average cost of water consumption is used to determine the price. In these estimations, the quantity of water usually appeared on both sides of the demand equation which may introduce a simultaneity bias, and the use of average cost is neither consistent with economic theory that would suggest that firms respond to marginal prices in the decision making process.

In this study, we examine the value of water for industry by estimating an industrial production function with a data set of about two thousand Chinese industrial firms. The purpose of the study is to evaluate the contribution of water use to the industrial production process and to explore sector specific differences in the value of water. In the empirical analysis, water is treated as an input in the production process, along with capital, labor, energy, and raw materials. A model on price elasticity of water demand associated with the marginal productivity approach is also developed and estimated by assuming the price being set equal to marginal cost of water use. To our knowledge, this is the first study of using the marginal productivity approach to estimate value of water use by industry.

Following this introduction, section II of this paper provides a brief review of previous research on industrial water demand and pricing, and presents the marginal productivity approach for valuing water of industrial use. A model for estimating the price elasticity of water demand is also provided in this section. The empirical study of Chinese practice of industrial water use is presented in section III. Section IV provides further discussions and concludes the paper.

II. The Models

Background

Emerging realities of rapid urbanization in developing countries have necessitated improvements in the pricing system of water supply and its success depends on understanding the willingness to pay (WTP) and the demand for the infrastructure services. International experience shows that pricing and effluent charges are potential instruments for industrial water savings by promoting investment in water recycling and water conservation technology (Bhatia and Falkenmark, 1993). As the potential for cost recovery seems to be directly related to service reliability and the role of water in the production process, it is also critical to understand the value of water in industrial production. Humplick, Kadat, and Madanat (1993) point out that most infrastructure provision in developing countries has been supply-driven resulting in non-performance from the user's point of view. However, the increasing costs of providing basic infrastructure to rapidly urbanizing areas during a period of budget declines, as well as a heightened interest in natural resource preservation and changing modes of infrastructure provision (public to private, or community based provision) has made it critical to examine demand driven approaches for infrastructure provision. In this context, it becomes important to get reliable estimates of the demand for water by understanding how water is valued by different and often competing user groups.

Despite the ubiquity of water use among manufacturing firms, there are surprisingly few studies that are concerned with the structure of industrial water demand. This situation stands in markedly contrast to the exhaustive analysis that has been applied to investigating the industrial demand for capital, labor, and energy (for example, Field and Gerbenstein, 1980; Halvorsen, 1977).

Industrial facilities use water for a variety of purposes. These include cooling and transporting intermediate inputs, producing steam, producing electricity, sanitation, and for inclusion in the firm's output (as in the food and beverage industries). There are only a handful of studies that have formally examined the role of water in industrial use. While most of these have been conducted in developed countries where water utilities have readily available information on price and consumption parameters.

The first generation of water use studies for industry were performed by estimating single equation water demand models where the ratio of total expenditures to total quantity purchased was used as a proxy for price (Turnoskvsky, 1969; Rees, 1969; and DeRoy, 1974). Extensions of these analyses have included the estimation of translog costs functions where water is included as an input along with labor, capital, and materials, and the average cost of water is used to determine the price (Grebenstein, 1979; Babin et. al, 1982). Most of these studies use the average cost of water as an indicator of price.

Renzetti (1988) examined industrial water use by examining firm level data on water use and expenditures for British Columbia manufacturing firms in 1981. He considered four separate aspects of water use in the analysis: intake, treatment prior to use, internal re-circulation, and discharge. The prices of water treatment, re-circulation, and discharge were proxied by their respective average costs and output was measured by total labor hours. A Cobb-Douglas cost function was used to derive the demand function and it was found that intake price elasticity of water ranged from -0.12 (Petrochemicals) to -0.54 (Light Industries). Renzetti (1992) reports the general findings suggesting that water demand was inelastic.

These estimation procedures are not flawless. For example, appearance of the quantity of water on both sides of the demand equation may introduce a simultaneity bias. The use of average cost mechanisms is also not consistent with economic theory that would suggest that firms respond to marginal prices in the decision making process.

In the following, a marginal productivity model will be developed for valuing industrial use of water and applied using data from two thousands of Chinese industrial firms, where water, as well as capital, labor, energy and raw materials, is treated as an input to a production function. A model on price elasticity of water demand associated with the marginal productivity approach are also developed and estimated. Our survey of the literature indicates that this is the first time such an analysis is being conducted with real data.

Marginal Productivity

There is a large body of literature on estimating production functions. The origin of the work on production functions can partly be attributed to the works of Cobb and Douglas (1928), who suggested the existence of laws of production governing the proportion of productive factors. The actual distribution of output into factors like capital and labor were consistent with estimated values of their parameters, and thus the productive factors received their marginal values. The Cobb-Douglas production function has been widely used in the empirical analyses of production and factor markets (see for example, Intriligator, 1965; Lau and Yotopoulos, 1971; and Nerlove, 1965). The function is well behaved in terms of monotonicity and convexity. However, there are important limitations associated with this function partly due to assumptions of additivity and homogeneity, as they imply that factor shares are constant and the elasticity of substitution as well as the Allen-Uzawa cross-partial elasticity of substitution are limited to unity.

In response to the additivity and homogeneity restrictions imposed by the Cobb-Douglas production function, Christensen, Jorgenson, and Lau (1973) proposed an alternate representation of the production possibility frontier which is a second order approximation of the quantities of inputs. The frontiers are quadratic in the logarithms and are called transcendental logarithmic or translog production functions. Christensen et al. show that the translog frontier is flexible by providing a greater variety of substitution of transformation patterns than those restricted by constant elasticity of substitution. The translog production function is widely used in the examination of production technology and factor markets (Chung, 1994). For example, using the translog production function, Berndt and Wood (1975) examined the structure of technology in US manufacturing and found that there are technological possibilities of substitution between energy and non energy inputs. Specifically, they find that energy is price responsive and energy and labor are substitutable to a limited extent. Halvorsen (1977) estimated a demand function using a translog function for US manufacturing and found that aggregate manufacturing demand for energy was highly price responsive but varied by type of energy.

For the purposes of our study, we assume the existence of a twice differentiable aggregate production function for the industrial sector. In the production function, output Y is related to the availability of five inputs: capital (K), labor (L), water (W), energy (E), and other raw materials (M). We also assume that the production function is characterized by constant returns to scale and any technical change affecting K, L, W, E, and M is Hicks neutral.

A production function with capital, labor, water, energy and materials as inputs can be specified as:

$$\ln Y=\beta_0+\beta_1\ln K+\beta_2\ln L+\beta_3\ln W+\beta_4\ln E+\beta_5\ln M+\beta_6\frac{\ln^2 K}{2}+\beta_7\frac{\ln^2 L}{2}+\beta_8\frac{\ln^2 W}{2}+\beta_9\frac{\ln^2 E}{2}+\beta_{10}\frac{\ln^2 M}{2}+\beta_{11}\ln K\ln L+ \\ \beta_{12}\ln K\ln W+\beta_{13}\ln K\ln E+\beta_{14}\ln K\ln M+\beta_{15}\ln L\ln W+\beta_{16}\ln L\ln E+\beta_{17}\ln L\ln M+\beta_{18}\ln W\ln E+\beta_{19}\ln W\ln M+\beta_{20}\ln E\ln M+\varepsilon \quad (1)$$

where,

LnY = log of value of output;

Ln K = log of capital;

Ln L = log of labor;

Ln W = log of later used in the production process;

Ln E = log of energy use;

Ln M = log of raw materials.

The quadratic nature of the function allows regularity to be held locally, and the function is monotonic and convex, thus being well behaved in these regions. The elasticity of output with respect to each factor of production is calculated by taking the partial derivative of output with respect to the factor under consideration. For example, the water elasticity of output is:

$$\sigma = \frac{\partial \ln Y}{\partial \ln W} = \beta_3 + \beta_8 \ln W + \beta_{12} \ln K + \beta_{15} \ln L + \beta_{18} \ln E + \beta_{19} \ln M \tag{2}$$

The marginal value of water in industrial production then is,

$$\rho = \frac{\partial Y}{\partial W} = \frac{\partial \ln Y}{\partial \ln W} * \frac{Y}{W} = \sigma \frac{Y}{W} \tag{3}$$

In a similar fashion, it is possible to calculate the marginal values of capital, labor, and other factors of production that are introduced into the equation.

Price Elasticity

Assume a water price P is set equal to the marginal cost of water use. For a profit maximization firm, the marginal value of output would be equal to the marginal cost. Then the water price P would be equal to the marginal value of water (ρ). Define γ as price elasticity of water use, which can be derived as,

$$\gamma = \frac{\partial \ln W}{\partial \ln P} = \frac{\partial \ln W}{\partial \ln \rho} = -\frac{\sigma}{\sigma - \sigma^2 - \beta_8} \tag{4}$$

γ can be estimated with water elasticity of output (σ) and coefficient β_8 in the production function ln*Y*.

III. The Empirical Study

Industrial Water Use in China

Water shortages are a chronic problem in China, where people are relatively poor in water resources, especially in the northern area. Per capita water resource in China on average is less than one third of the world average, while in the north it is only about 10 percent. The temporal disparity of rainfall aggravates water shortages and causes devastating floods and droughts in major river basins[ii]. In northern China, a decade-long drought, compounded by rapid population growth, industrialization and uncoordinated management, has depleted several famous lakes and reduced several great rivers such as the Yellow River to dwindling streams. Groundwater is over extracted and in many areas groundwater tables have dropped by 100-300 meters, which causes many buildings to collapse. It is estimated that more than 400 of China's 600 cities are short of water and about 100 face serious water shortage problems.

While water shortages have been a serious threat in China, widespread pollution makes China's water problems even worse. Most of China's bodies of water are becoming increasingly contaminated by industrial and municipal wastewater discharges as well as agricultural runoffs from chemical fertilizers, pesticides, and animal manure. Urban bodies of water are among the most polluted because they receive large amounts of untreated industrial and municipal wastewater. Many urban river sections and some large freshwater lakes are so polluted that they can not even be used for irrigation. Groundwater quality has also been declining, especially in the north where groundwater is used intensively to compensate for the lack of surface water. Coastal waters have also experienced a rapid decline in water quality.

While irrigation is the primary user of the scarce water resources, water consumption for industrial use has been growing. In 1980, industry consumed about 46 billions of cubic meters of water, while in the year 2000 the number is projected to be 177 billions, which accounts for over 20% of the total projected water consumption.

China's industries have started to conserve water. Water recycling rate is increasing. However, much can and should be improved. For example, China's inefficient factories use 20 times the amount of water than Western factories use to produce one ton of steel.

The government recognizes the potentially dire consequences of inaction on the water issue. Measures on both sides of water demand and supply have been taken since the beginning. The Chinese government is seriously considering its most ambitious water-diversion project, a plan to pump water from the swollen Yangtze River in the south into the failing Yellow River. That would require pumping Yangtze water up to 800 miles north, over mountains as high as 14,000 feet. Some limited steps toward water conservation are being taken. The government is investing in water-saving technology for farmers and industry, is beginning to charge urban residents higher water fees, and at least in theory, has established a rationing system along the Yellow River (SEPA, 1995).

However, more dramatic and systematic changes are needed if China is to make itself work on its water scarce budget. It must switch to less water-intensive crops and industry, and must stop subsidizing water prices, to force industry to conserve water. China's water supply and wastewater treatment services are generally under priced, leading to excess demand, high pollution, and inadequate funds to meet investment needs. Higher prices would encourage large water consumers in industry and agriculture to adopt more efficient water use practices and technologies. However, so far there is no empirical study available on price elasticity of water demand and the value of water across different sectors to help devise pricing policies in China.

Data

During the course of our collaborative policy research with China's State Environmental Protection Administration (SEPA), SEPA provided us a data set including detailed plant-level information in 1993 of more than 2000 factories. Factories in the sample were mostly medium and large state-owned enterprises which are under close monitoring by the government due to environmental reasons. Data were double-checked by staffs from both the enterprises and the government who held legal responsibilities for the accuracy. Variables in the data set include plant characteristics, water and energy consumption, pollution discharge and treatment, as well as capital, labor, and some raw materials. Table 1 provides a summary of the variables that were used in the study.

As the original data set was collected for the purpose of pollution control analyses, it is of reliable quality, but the data set has some missing values on variables such as energy use and raw materials. For energy use, information is available only for about 200 firms. Data on several types of raw materials are only available for dozens of firms, which do not permit a reliable estimation of production function. Fortunately, residuals of production processes are available for almost all observations, based on which instruments for raw materials can be constructed as $M = \lambda^* R$, where M is the raw materials used in the production process; R is the residuals; λ is a coefficient which is a function of sector, technology, and production efficiency, etc..

Estimation Results

Table 2 presents estimation results of three models. Model A is a basic Cobb-Douglas function, and model B is a trans-log function as presented in equation (1), while model C is a trans-log function with joint effects of water on industrial output by sector included. Variables included in these models are capital (K), labor (L), water (W), residuals of materials – chemical oxygen demand (C), firm's ownership and scale as defined by Chinese accounting system, and location of firms. Consistent results are obtained with all three models. Capital, labor, water and residuals all have positive significant elasticity. Firms located in the coastal areas or with larger scale have higher production efficiency. These results are consistent with a-priori expectations as large regional disparities in economic efficiency exist between the coast and the interior regions. But for publicly owned industrial firms, the production efficiency is lower.

With model C, we estimated the joint effects of water on industrial output by sector. In this variation, we took the product of the amount of water consumed with the sector dummies. In this process, we are able to account for differences in the output effects of water across industries. Theoretically, while the sector dummy would account for a change in the intercept term, the joint effect of sector and water consumption would also include a change in the slope. This treatment allows us to have better estimates of marginal value of water for different sectors.

During the analysis, the presence of econometric problems that are often associated with the estimation of single equation models using cross section data were tested. The White's Test was used to examine the presence of heteroscedasticity, and results indicated its presence in our models. In our estimations, we used the White (1980) formulation of a heteroscedasticity consistent covariance matrix estimator that provides correct estimates of the coefficient co-variances in the presence of heteroscedasticity of an unknown form. We also tested whether the translog form was more appropriate than the Cobb-Douglas function for estimating the production function. The Wald Test was used by restricting the coefficients for the interaction terms to zero. The Wald Test indicated that the restrictions were not valid and trans-log functions were better than the Cobb-Douglas specification in fitting the data. We performed the Walds coefficient restriction test to examine whether the interaction terms of water consumption and sector were statistically valid or whether they equaled to zero. The null hypothesis of the interaction terms being zero was rejected, concluding that there are significant sector-specific differences in the output elasticity of water. Thus, the trans-log model with joint effects of water and sector was used in the estimation of marginal values.

In Table 3, we present the output elasticity of water (σ) and the marginal value of water (ρ) by sector using the specification in model C. These output elasticity and marginal values are calculated by using equation (3) and (4) for elasticity and marginal value of water with sample average data of variables in the model for each sector. The industry-wide average output elasticity of water is about 0.17. And the marginal value of the Chinese industry is about 2.45 Yuan per cubic meter. Results presented in Table 3 show large variations in the marginal value of water across sectors. These values range from the high value of 26.8 Yuan/ton in the transportation equipment sector to low values of 0.05 Yuan/ton in the power generation sector. In addition, there are large variations between regions in the average marginal value of water, with the marginal value in the north being almost twice that of the south. These results reinforce the acute water problems in the north, where the relative water scarcity puts a higher value of water use.

Table 3 also provides price elasticity of water use (γ) by sector. The price elasticity was calculated by the specification in equation (4) and the price elasticity of water for the whole Chinese industry is estimated to be about -1.

IV. Discussion and Conclusion

This study is the first one, to our knowledge, using the marginal productivity approach to estimate marginal values of water for industries. In our empirical model, water, as well as capital, labor and raw materials, are treated as inputs to industrial production. Trans-log functions are specified with dummies for firms' characteristics such as sector, ownership and location, etc. to differentiate production efficiencies as well as water values. Given the value of output, the marginal values of water can be derived by taking the derivatives. Assuming that firms are profit maximizing, they would use water to an extent where the marginal cost equals the marginal value of output. Price elasticity of water use can then be derived by setting the price equal to the marginal value of output. The formula shows that with a trans-log specification of a production function, the price elasticity of water use can be determined by the output elasticity of water use as well as the coefficient of squared term of water use in the trans-log production function.

In literature, cost functions and demand functions have been employed to estimate value of water use by industry. Theoretically, the marginal productivity approach is a dual to the cost function approach, as the marginal cost should be equal to marginal value of production given the assumption that firms are maximizing profits. A demand function can also be derived from the first order condition of the profit maximization problem. The results with the three approaches should be consistent. Inconsistent results may be found when prices are distorted or firms are not maximizing profits. In these case, a marginal productivity may be a better estimation of water value since it reflects the maximum that a firm is willing to pay for water consumption.

Serious water shortages in China, and many other regions, have made it necessary to manage water demand with appropriate pricing policies. Efficient pricing policies can only be established with analyses on water demand and value in an actual setting. This empirical study represents such an effort in providing guidelines for setting water prices for Chinese industries. Using data from about two thousands of Chinese industrial firms, this study estimates marginal values of water use in industrial productivity for different sectors. Price elasticities of water demand are also estimated with reasonable assumptions. The marginal values estimated vary from 0.05 Yuan per cubic meter for power sector to 26.8 Yuan per cubic meter for transportation equipment, with an average for the whole industry of 2.45 Yuan per cubic meter, which is a very low estimation. However, these numbers contrast the current practice of water pricing in China which is in a range of 0.70 to 1.20 yuan[iii] (World Bank, 1997). In the light of these results, it would not be unreasonable for water utilities to increase prices, as the marginal values are reflective of the willingness to pay for the service. Further the estimated price elasticity of water demand is about -1.0, suggesting that pricing policies can be a potential instrument for water conservation[iv]. In order for water pricing to be an effective policy instrument for water conservation, the water price should be set much higher than the estimated marginal water productivity.

Caution should be given in extrapolating the marginal value estimates of this study to small-scaled industries because the sample used in this study are drawn from those top industrial water polluters in China which are mostly large and medium sized enterprises. In our sample of 1993, the average productivity of water (i.e., value of output divided by water consumption) is about 15 yuan per cubic meter of water. According to Chinese year books, the number was about 24 in 1993 for the whole industry of China. The marginal value of water then was about 3.92, rather than 2.45, yuan per cubic meter. This higher value reinforces the argument that China should increase the water price substantially to save water.

References

Altaf, M. A. (1994). Household demand for improved water and sanitation in a large secondary city: findings from a study in Gujranwala, Pakistan. Habitat International 18, 1:45-55 1994

Altaf, M.A. and Hughes, J.A. (1994). Measuring the demand for improved urban sanitation services: results from contingent valuation study in Ouagadougou, Burkina Faso. Urban studies, 31, 10. 1763-76.

Babin, F., C. Willis, and P. Allen. (1982). "Estimation of Substitution Possibilities between Water and Other Production Inputs." American Journal of Agricultural Economics 64 , 1, 148-51.

Berndt, E., and Wood, D. (1975). "Technology, prices, and the derived demand for energy." Review of Economics and Statistics. 57. 259-268.

Bhatia, R. and Falkenmark, M. (1993). Water Resource Policies and the Urban Poor: Innovative Approaches and Policy Imperatives. Washington DC: World Bank.

Cobb, C. and Douglas, P. (1928). "A theory of production." American Economic Review, 18. 139-165.

Christensen, L., Jorgenson, D., and Lau, L. (1973). "Transcendental logarithmic production function frontiers." Review of Economics and Statistics. 55. 29-45.

Chung, J.W. (1994). Utility and Production Functions. Blackwell: Oxford.

DeRooy, Y. (1974). "Price Responsiveness of the Industrial Demand for Water." Water Resources Research 10, 3 403-6.

Field, B., and Grebenstein, C. (1980). "Capital-energy substitution in U.S. manufacturing. Review of Economics and Statistics. 62. 207-212.

Grebenstein, C., and B. Field. (1979). "Substituting for Water Inputs in U.S. Manufacturing." Water Resources Research 15,2, 228-32.

Halvorsen, R. (1977). "Energy substitution in U.S. manufacturing." Review of Economics and Statistics. 59. 381-388.

Humplick, F., Kudat, A., and Madanat, S. (1993). "Modeling Household Responses to Water Quality: A Service Quality Approach." TWURD Working Paper # 4. Washington DC: World Bank

Intriligator, M. (1965). "Embodied technical change and productivity in the United Kingdom, 1929-1958." Review of Economics and Statistics XLVII. 65-60.

Kessides, C. (1993a). "Institutional Options for Provisions of Infrastructure." World Bank Discussion Paper No. 212. Washington, DC.

Kessides, C. (1993b). "The Contributions of Infrastructure to Economic Development: A Review of Experience and Policy Implications." World Bank Discussion Paper No. 213, Washington, DC.

Lau, L. and Yotopoulos, P. (1971). "A test for relative efficiency and an application to Indian agriculture." American Economic Review, 61. 94-109.

McPhail, A.A. (1994). Why don't households connect to the piped water system? Observations from Tunis, Tunisia. Land Economics. 70, 2 189-96.

Nerlove, M. (1965). Estimation and Identification of the Cobb-Douglas Production Function. Chicago: Rand McNally.

Rees, J. (1969). Industrial Demand of Water: A Study of South East England. London: Weidenfeld and Nicolson.

Renzetti, S. (1988). "An Econometric Study of Industrial Water Demands in British Columbia, Canada." Water Resources Research 24, 10, 1569-75.

Renzetti, S. (1992). "Estimating the structure of industrial water demands: the case of Canadian manufacturing." Land Economics, 68, 4 396-404.

Renzetti, S. (1993). "Examining the difference in self- and publicly supplied firms' water demands." Land Economics, 69, 2, 181-88.

Rosegrant, M. and Meinzen-Dick, R. (1996). Water Resources in the Asia Pacific Region: Managing Scarcity. Asia Pacific Economic Literature. 10. 2.

SEPA (China State Environmental Protection Administration), 1995, China Environmental Protection Agenda in the 21st Century, China Environmental Sciences Press.

Singer, Rena, 1999, *The Philadelphia Inquirer*, February 1.

Singh, B. ET AL. (1993). "Rural water supply in Kerala, India: how to emerge from a low level equilibrium trap. Water Resources Reseach, 29, 7. 1931-1942.

Turnovsky, S. (1969). "The Demand for Water: Some Empirical Evidence on Consumers' Response to a Commodity Uncertain in Supply." Water Resources Research 5, 2, 350-61.

White, H. (1980). A Heteroskedasticity-Consistent Covariance Matrix and a Direct Test for Heteroskedasticity. Econometrica, 48, 817–838.

Whittington, D. (1991). Contingent valuation: estimating the willingness to pay for housing services: a case study of water supply in Southern Haiti Economic Development and Cultural Change, 38, 2. 293-311.

World Bank. (1994). World Development Report: Infrastructure for Development. Oxford University Press, New York.

World Bank (1995). China: Regional Disparities, BR#14496-CHA. Washington DC: World Bank.

World Bank, (1997). Clear Water, Blue Skies: China's Environment in the New Century, Washington, DC.

Table 1: Variables used in the empirical analysis

Variable	Reported Units	Mean	SD
Value of Industrial Output (Y)	Ten thousand Yuan	14,939	35,687
Capital (K, original value of fixed assets at the end of the year)	Ten thousand Yuan	14,132	36,646
Labor (L, number of workers)	Number	3,342	17,294
Water Use (W, total amount of water consumed in production)	Ten thousand tons or cubic meters.	1,027	1,755
COD (C)	Units consumed	1,399	3,821
Firm Size	Dummy Variable (1 for large)	37% Large	
Ownership	State Owned =1	91% State	
Regional Characteristics[v]	Dummy variables for South Coast, North Coast, and South Internal Region		
Sectoral Differences	Dummy variables for various sectors		

Table 2: Estimations from various specifications

Dependent Variable: Industrial Output	*Model A (Cobb Douglas)*	*Model B (Trans Log)*	*Model C (Trans log with sector dummies)*
Ln K	0.36***	0.80***	0.68***
Ln L	0.46***	1.36***	0.83***
Ln W	0.08***	-0.57***	-0.04
Ln C	0.05***	0.16**	0.02
Ln K* Ln L		-0.17***	-0.14***
Ln K * Ln W		-0.03	-0.01
Ln K* Ln C		0.01	0.005
Ln L* Ln W		0.17***	0.06**
Ln L * Ln C		-0.04**	-0.005
Ln W * Ln C		0.02**	0.0006
½ LnK^2		0.10**	0.09**
½ LnL^2		-0.02	0.07*
½ LnW^2		-0.07***	-0.02
½ Ln C^2		-0.006	0.012**
S1*ln(water) Coal Mining			-0.13***
S2*ln(water) Petroleum Extraction			-0.02
S3*ln(water) Metal mining and preparation			-0.07***
S4*ln(water) Food and beverage manufacturing			0.01
S5*ln(water) Textiles			0.04**
S6*ln(water) Paper and pulp products			-0.07***
S7*ln(water) Power generation			-0.14***
S8*ln(water) Petroleum			0.09***
S9*ln(water) Chemicals			-0.03***
S10*ln(water) Medical Products			0.04***
S11*ln(water) Construction			-0.03
S12*ln(water) Smelting			0.05***
S13*ln(water) Industrial equipment and machinery			0.003
S14*ln(water) Transportation Equipment			0.07**
S15*ln(water) Electronic Equipment			0.06*
S16*ln(water) Leather goods			0.09**
South Coast	0.42***	0.40***	0.39***
North Coast	0.12***	0.10**	0.14***
Large Firm	0.32***	0.28***	0.21***
Public Ownership	-0.20***	-0.20***	-0.21***
Constant	1.37***	-2.14***	-0.65
Adj R^2	0.72	0.74	0.79
Number of Obs.	1704	1704	1704
F Statisitc	565.58***	277.50***	181.79***
SSR	885.32	819.4	690.70

Note: *** significant at .01 significance, ** .05 significance, * .10 significance

Table 3: Marginal Value of Water by Sector

Sector	Output Elasticity of Water (σ)	Marginal Value of Water(ρ, Yuan/ Ton)	Price Elasticity of Water (γ)
Coal Mining	0.04	1.16	-0.63
Petroleum Extraction	0.15	6.07	-0.99
Metal mining and preparation	0.09	0.90	-0.85
Food and beverage manufacturing	0.17	2.57	-1.04
Textiles	0.21	11.50	-1.10
Paper and pulp products	0.10	0.84	-0.88
Power generation	0.03	0.05	-0.57
Petroleum	0.25	5.43	-1.19
Chemicals	0.13	0.98	-0.96
Medical Products	0.21	3.26	-1.10
Construction	0.14	5.50	-0.98
Smelting	0.21	3.82	-1.11
Industrial equipment and machinery	0.17	8.90	-1.03
Transportation Equipment	0.24	26.83	-1.16
Electronic Equipment	0.23	24.41	-1.14
Leather goods	0.26	17.46	-1.20
INDUSTRY WIDE	**0.17**	**2.45**	**-1.03**

Note: Estimation made with translog specification with sectoral dummies

[i] For reference, see Altaf et al. (1989), Singh et al (1993), Briscoe and Whittington (1991), Altaf (1994), Altaf and Hughes (1994), McPhail (1994), and Whittington (1991). Most of these studies in developing countries have focused on estimating the demand response of households when faced with various pricing as well as source options. By extension, the value of water for household use has been estimated in several parts of the world. Several household studies have examined the user demand for water services provided by a utility by either examining the willingness to pay for connections to existing service networks such as piped water systems or for improved services.

[ii] Such a pattern requires extensive water storage to ensure a stable supply.

[iii] Price is lower for self extraction.

[iv] According to World Bank (1995), the price elasticities of industrial water demand in developing countries are generally in a range of –0.45 to –1.37.

[v] Firms on the south coast include those in the provinces of Guangdong, Fujing, Jiangsu, Shanghai, and Zejiang. Firms on the North Coast include those in Shangdong, Tianjin, Beijing, Lioning, and Hebei. Firms in the South Internal Region include those in Jiangxu, Hunan, Guangxi, Euizhou, Yurnan, and Sichuan.

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